# Development of an Integrated Cost Estimation and Cost Control System for Construction Projects

by

**Salman Azhar, Syed M. Ahmed and Amaury A. Caballero**

Florida International University
10555 W. Flagler Street, Miami, Florida 33174, USA

ABSTRACT

Today, most of the construction companies are using computer-aided softwares for cost estimation and cost control. The cost estimation is done before the construction begins while the cost control is performed during the construction period. The organization which controls the cost could be different from the organization which prepares the cost estimate. Moreover, different softwares are available for cost estimation and cost control. This may complicate the cost control process due to inconsistencies between the cost estimation and cost control data. The purpose of this study is to develop a system which could integrate the cost estimation and cost control processes. Such integration enables the transfer of cost estimation data automatically to the cost control process. Therefore, complete information regarding the cost status of the project can be accessed at any time. Systems Analysis and Design (SAD) approach using relational database management system is used to develop the integration model. MS Access™ is used as a physical tool to implement and test the system. This paper provides a glimpse of the requirements analysis, system development and implementation stages.

KEYWORDS

Cost Estimation; Cost Control; Cost Integration; Cost Engineering; Construction Softwares, Data Modeling

## 1. INTRODUCTION

Cost engineering consists of cost estimation and cost control. Estimation is a methodology for forecasting and predicting cost and expenditures of a future project and to produce a budget. Cost control is a process to hold expenditures within the budget by monitoring and appraisal of the cost performance (Clark and Lorenzoni, 1997).

In most construction projects, cost estimation and cost control are performed by different people (e.g. estimation is done by quantity surveyors or estimators while cost control is the responsibility of the owner or contractor's cost engineers) and sometimes by different organizations using different techniques and/or softwares (Kibler, 1992). Due to these reasons, the cost estimation and cost control data are usually available in different forms and at different levels of detail. This inconsistency of data results in lack of accuracy and untimely generation of cost control reports for any corrective decision making (Cagle, 1991).

However, if the estimation and control processes are integrated, there will be a communication of information between the two processes. The results of the cost control process can be used as a feedback to the estimation process for future projects, while a good estimate may make the control process more effective.

Therefore, this study is conducted with the objective of developing an integrated cost estimation and control system which could facilitate the transfer of information between the two processes for current and future projects. The system identifies the linkages (common attributes) between the two processes and

presents a data flow schema to implement it in the real life using any database management software such as MS Access™ or Oracle™.

## 2. METHODOLOGY

Due to its inherent simplicity, systems analysis and design (SAD) approach is selected to develop the integration model and the prototype software (Whitten et al., 2001). The framework selected for this research is outlined in Figure 1, which consists of three steps with interlinked inputs and outputs.

### 2.1 Requirements Analysis

There are three types of requirements which were identified for developing the cost integration model. These are cost estimation software requirements, cost control software requirements and the requirements for their integration. For this purpose, the existing cost estimation and control softwares were explored to identify their vital attributes which could be used for integration. Such attributes included the cost and work activities coding system, techniques to measure different processes, and input and output formats.

### 2.2 Integrated Model Development

The integrated model development begins by developing the individual data schemas for cost estimation and cost control parts. This is done by plotting the logical dataflow diagrams (DFD) for each part, which provided a key to integrate both parts. This process is briefly illustrated in Figure 2.

In the next step, the data requirements of the integrated cost estimation and control processes are identified. These data requirements are then combined to prepare an integrated data model (i.e. an Entity-Relation (E-R) diagram) which serves as a basis to construct prototype software.

### 2.3 System Development and Testing

MS Access™ is used as commercial-of-the-shelf tool to develop prototype software using the integrated model developed in the second step.

After the prototype is created, its testing is conducted to determine any errors, problems and feedback for improvement.

## 3. REQUIREMENTS ANALYSIS

### 3.1 Coding System

CSI MASTERFORMAT is used for cost estimation and control coding which assigns a specific activity id to each individual activity (O'Connor, and Caraway, 1993). The activity id is divided into 4 parts: 1_id, 2_id, 3_id, and item_id representing major item, minor item, type of construction and the location. For example, activity id 03 010 020 001 shows formwork and support for concrete columns in the first floor of the building.

### 3.2 Cost Estimation and Control Processes

Cost estimation includes estimates for materials, labor, equipment and subcontracts. For the sake of simplicity, lump sum contract is used in this study. Therefore, the format of estimating model consists of work package cost plus markup and overhead as a percentage of total work packages cost for overall project.

The cost control model is based on the earned value concept, consisting of three elements: actual cost of work performed (ACWP), budgeted cost of work performed (BCWP) and budgeted cost of work scheduled (BCWS).

ACWP for material = total amount paid for materials in a work package
ACWP for labor = total amount paid to labor for a work package
ACWP for equipment = total amount paid for equipment assigned to a work package

BCWP for material, labor or equipment = percent work progress multiplied by total cost of labor or equipment or material in a work package

BCWS for material, labor or equipment = total estimated cost for labor, equipment, or material at the control time.
On the basis of these parameters, cost variances and schedule variances are calculated to

determine work productivity which is used to measure the rate of work progress.

## 3.3 Input and Output Formats

The inputs for the system are the quantities of work packages, unit prices, work schedule and the daily progress data. The output will be cost estimates and cost control reports for overall or any specific part of the project.

## 4. MODEL DEVLOPMENT

### 4.1 Dataflow Diagrams

One basic requirement in the integrated cost estimation and cost control model is that the estimation data should be automatically transferred to the control part. Keeping this condition in mind, the logical data flow diagrams for both parts are designed. The logical dataflow diagram depicts how the system behaves without any physical implementation and provides a great tool in developing an information system.

Figure 3 illustrates the dataflow diagram (DFD) for estimation part. The 3-D rectangular boxes show the external agents which interacts with the system and provide necessary inputs. These inputs are then passed to different processes labeled in the logical order. Each process is linked with a certain database to store and/or retrieve the information. The most important process in the estimation DFD is process no. 3 which prepares the cost estimation sheet for material, labor, equipment and subcontracts. This estimation sheet which is developed before the construction stage of the project life cycle is used during the construction stage as a reference of cost. Therefore, the estimation sheet is combined with the project scheduling in order to track down the costs on daily basis.

Similarly, figure 4 shows the DFD for the cost control part. The major input is coming from the process no. 3 (i.e. estimation sheet) which is linked to the process no. 7 to map estimation part with the project schedule. The labor time card is used to assess the actual work of an employee for a work package. The labor time card combined with the labor unit price from the estimate storage (storage no.8.0) will produce actual labor cost of work performed (ALCWP), i.e. storage no.9.0.

The material card is used to assess the amount of material used for each work package on site. The material card combined with the material unit price from the estimate storage (storage no. 8.0) will produce an actual material cost of work performed (AMCWP), storage no. 10.0.

Actual equipment cost is similarly calculated from the equipment time card data which is collected from the site combined with the equipment unit price from the estimate storage (storage no. 8.0). However, the equipment idle cost should also be considered by calculating the type of equipment which is not used on that day (storage no.23). The cost of idle equipment will not be used directly in the work package, but it will be added in the calculations of cost variance for total project cost.

The ACWP of material, labor, and equipment will be used to find respective cost variances for each work package performed. This task can be achieved by combining the ACWP for material, labor, and equipment with the budgeted cost of work performed (storage no. 12, 13, and 14). The budgeted cost of work performed can be calculated by combining the quantity of work done and the unit price of material, labor and equipment from the estimate storage (process no. 11).

Finally, the cost variance for complete project can be found by combining the equipment idle cost (storage no.23) with the cumulative of cost variance for material, labor and equipment for the total work package done (storage no. 15, 16, and 17). The cost variance for total project is represented as process no. 18 in Figure 4.

For the purpose of using the cost control data for future projects, a database of labor and equipment productivity is developed. The labor productivity (process no.20) can be assessed from the actual labor cost of work performed storage (storage no. 9) multiplied with the

quantity done, and labor unit price from the estimate storage (storage no. 8.0). The productivity of equipment (process no. 21) can be assessed in the same way as labor.

The material waste is also considered for the future project estimation. The material waste could help the future estimator to estimate the waste of materials for a certain work package more accurately. The material waste (process no. 22) can be assessed from the actual material cost of work performed (storage no. 10) combined with quantity take off, material unit price, and conversion of material unit from the estimate data stored in estimate storage (storage no. 8.0)

## 4.2 Data Model

Based on the data needs as ascertained in the DFD's, a data model is prepared using the relation database concept as shown in Figure 5. The data model is normalized to the $3^{rd}$ degree to increase the processing speed of the prototype software.

## 5. SYSTEM DEVELOPMENT AND TESTING

Among the different commercial off-the-shelf softwares, MS Access™ is selected due to its user friendliness, cheap cost and easy availability. As a first step in prototype software development, data *Tables* are designed for material, labor, equipment, subcontracts and work progress. This was followed by *Query* design to establish the relations between different entities. Each process (as shown in Figures 3-4) is interpreted in the form of *Macros* and finally *Forms* are designed to get input and generate reports.

After development, the prototype software is tested on a number of projects to identify any errors and deficiencies (the software results are compared with the manual calculations). This process is repeated until no significant problems are found.

## 6. CONCLUSIONS

The purpose of integrating the cost estimation and cost control is achieved by using the relational database management system in Microsoft Access. Such integration enables the transfer of cost estimation data automatically to the cost control process. Therefore, complete information regarding the cost status of the project can be accessed at any time. The system provides different tools for controlling the project cost such as productivity data of equipment & labor, and materials waste data. Such information can enable the management to take preventive actions to control the total project costs. The productivity and materials waste data can also be used to prepare estimates for future projects.

## 7. RECOMMENDATIONS

The integrated cost estimation and control system in this study is designed for lump sum contract projects. There is a need to extend it for different contract types and enhance its usability for multitasks environment.

## 8. ACKNOWLEDGEMENT

## 9. REFERENCES

Cagle, R. F., 1991. Implementing an Owner's Cost Control System, *AACE Transactions,* O.7.

Kibler, B. E., 1992. Integrated Cost and Schedule Control: a piece of cake, *Cost Engineering,* Vol. 34, No. 7

Lorenzoni, D.C., and Clark, F.D., 1997. *Applied Cost Engineering*, $3^{rd}$ edition, Marcel Dekker, Inc., USA.

O'Connor, J.T., Caraway, P.H., 1993. Need for Specification Format That Accommodated Engineered Projects, *Journal of Construction Engineering and Management*, Vol.119, No.4

Whitten, L.J.; Bentley, L.D.; and Dittman, K.C., 2001. *Systems Analysis and Design Methods*, McGraw-Hill Higher Education, USA.
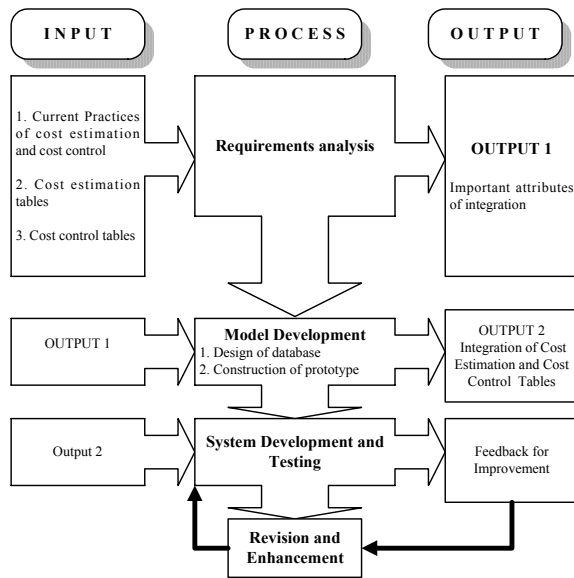
Figure 1. Basic framework to develop an integrated
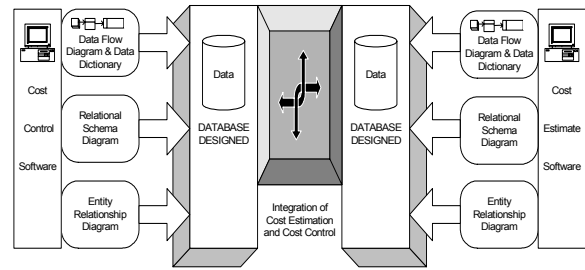cost estimation and control system



Figure 2. Integrated cost estimation and cost
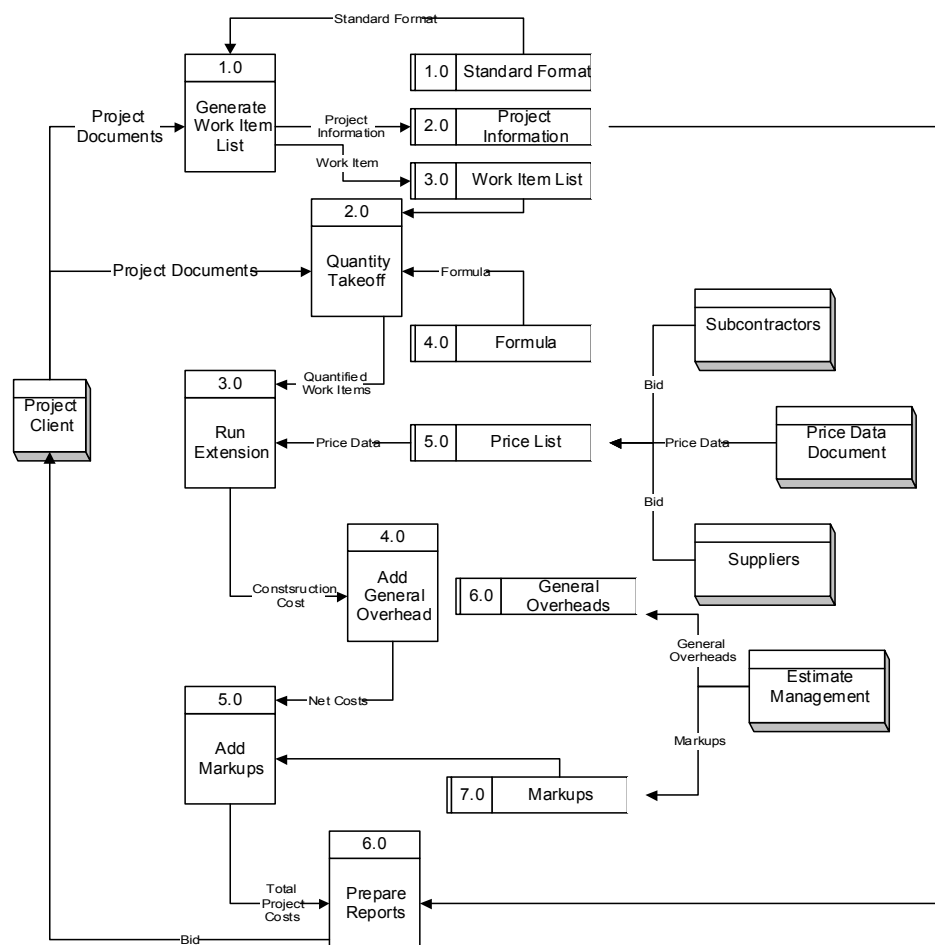control model development concept



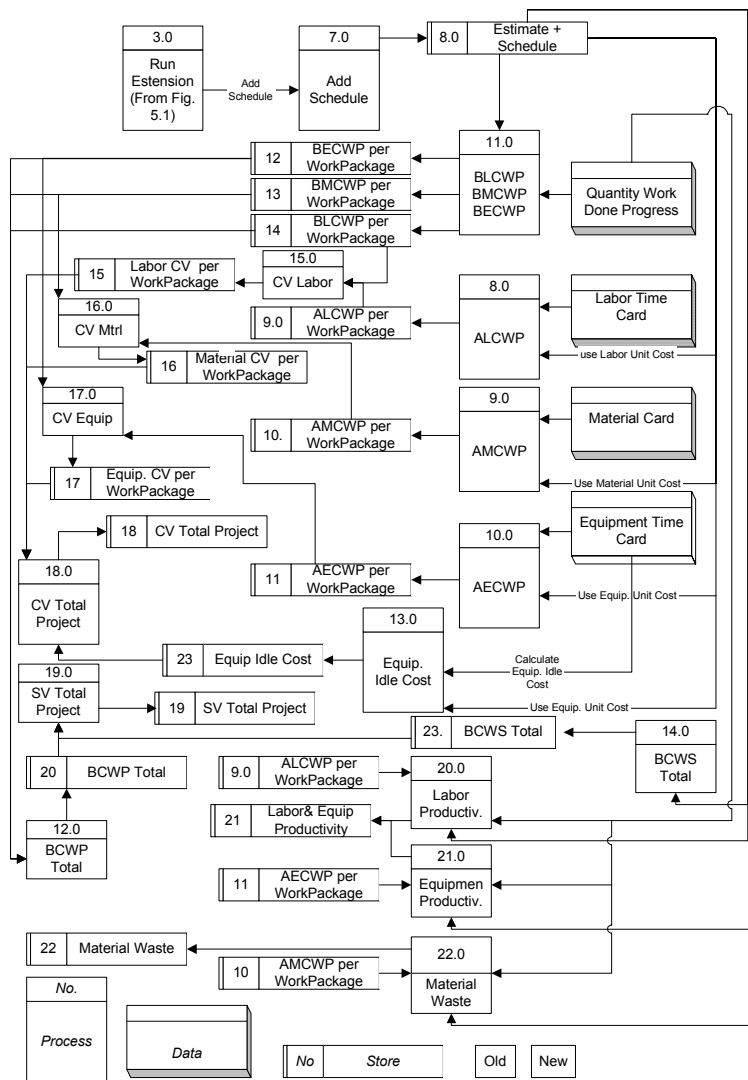Figure 3. Data flow diagram for cost estimation

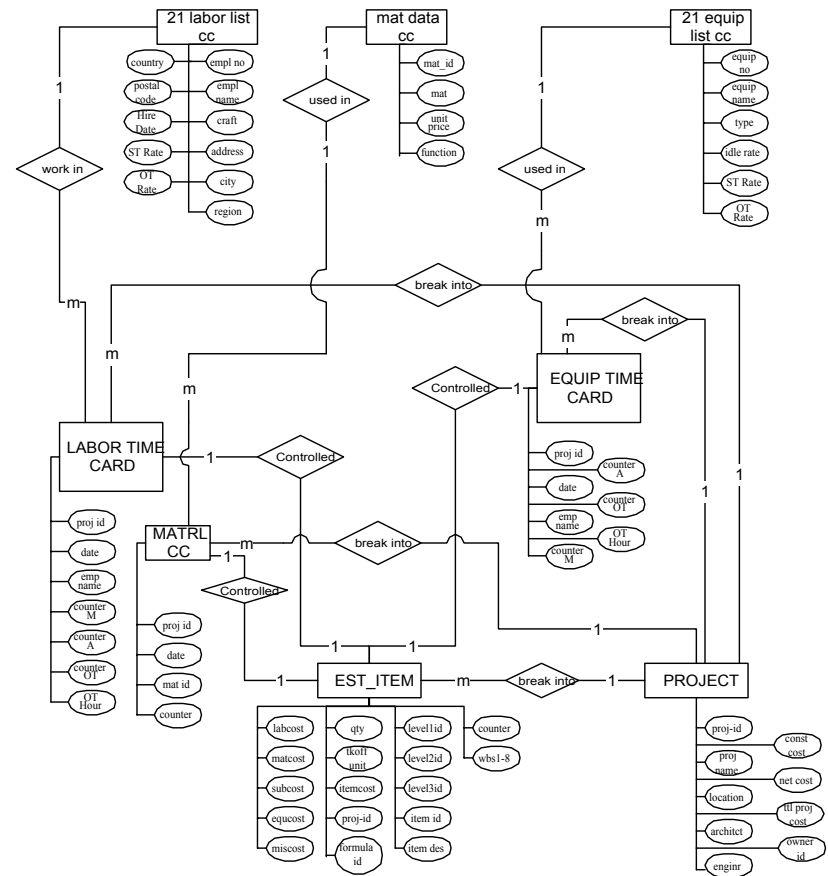Figure 4. Dataflow diagram for cost control



Figure 5. Data model for integrated cost estimation and cost control system